ERIM International Inc. Demo Products: Ships and Winds

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ERIM International Inc. Demo Products

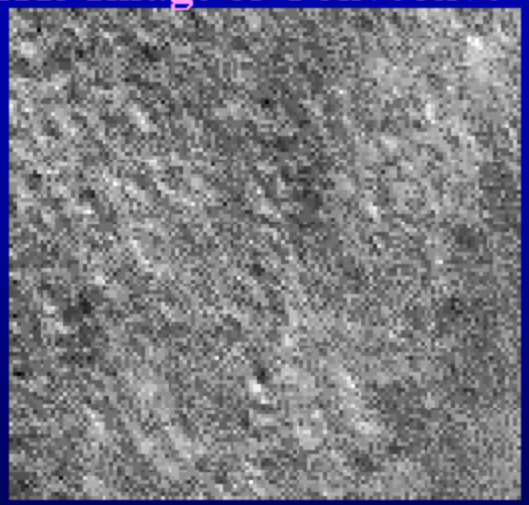
- Wind vector estimation
- Ship locations
- Future algorithms

Wind Vector Estimation From SAR

SAR images over the ocean contain signatures of atmospheric effects due to the local changes to wind speed and direction that they cause on the surface. These signatures are often elongated in the general direction of the local wind.

=> may be able to estimate local wind direction using elongation of image signatures

ERS Image of Convective Cells



ERS Image of Wind Rows

Wind Vector Estimation From SAR (cont.)

The radar cross section of the ocean is a function of the local wind speed and wind direction with respect to the SAR look direction

$$\sigma_o = a(\theta)U^{\gamma}[1 + b(\theta, U)\cos(\phi) + c(\theta, U)\cos(2\phi)]$$

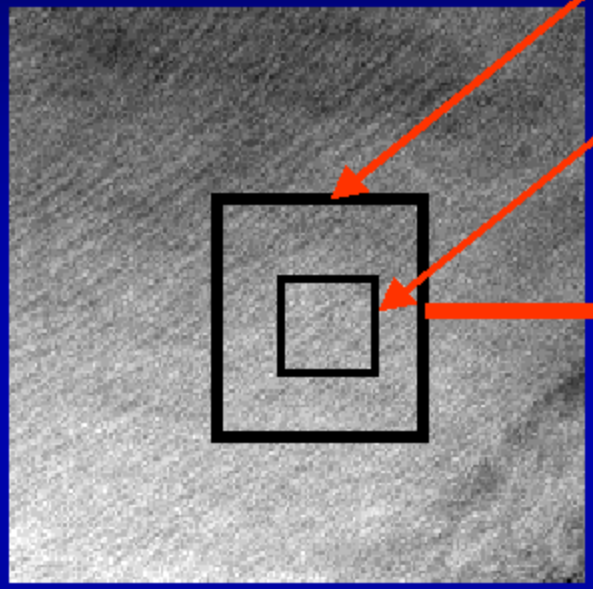
U = wind speed, θ = incidence angle, ϕ= wind direction
γ,a,b,c are model parameters

=> combining σ_o with wind direction may estimate wind speed

Estimating Wind Direction From SAR

Region to use to estimate a wind vector

Region to use to generate a spectrum from the image



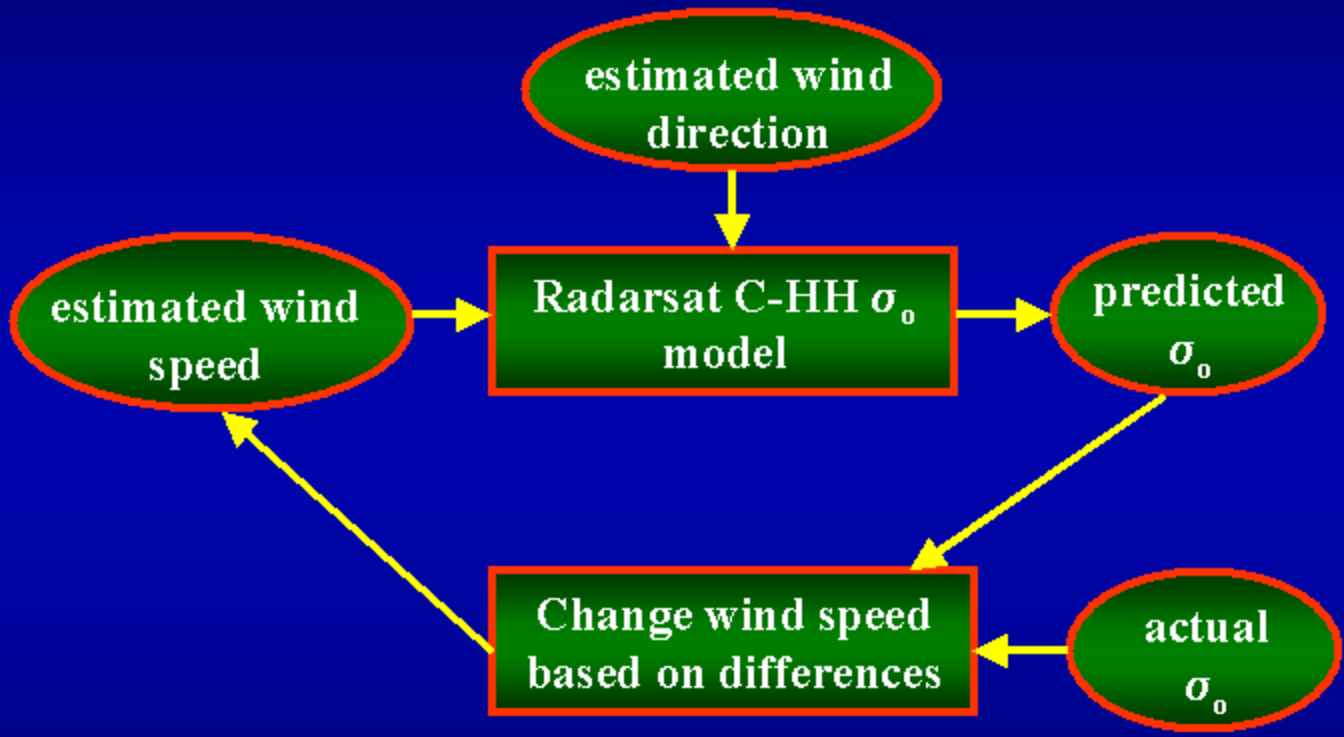
Form a smoothed spectrum by calculating a spectrum over multiple placements of the smaller region, then averaging the spectra

Calculate the elongation direction of the spectral energy over large scales (3 - 20 km), wind direction is rotated 90 degrees from this direction
(red=estimate, white=actual)

Estimating Wind Direction From SAR (cont.)

- Wind direction estimates have a 180 degree ambiguity
- Direction of large-scale spectrum elongation is estimated by either:
  - fitting a quadratic polynomial to the spectrum and calculating the direction of smallest curvature (best one)
  - finding the peak value with the large-scale region
- Land is masked out using a coastline map
  - 500m uncertainty is added for registration errors

Estimating Wind Speed From SAR



Iterate on the estimated wind speed until the error between predicted and actual σ_o is minimized.

Developing a Radarsat C-HH RCS Model

- Much work has gone into developing a C-VV RCS model for ERS work (e.g. CMOD4)
- A model for C-HH still needs to be developed and validated
- ERIM Int. is investigating an additional approach to APL's
  - use standard two-scale model
  - modify the equilibrium spectrum near the C-band bragg wave to match CMOD4
  - scale the hydrodynamic function for Radarsat

Two-Scale Model With Hydrodynamic Effects

$$\sigma_o = \iint \sigma_b(s_u, s_c)[1 + h(s_u, s_c)]p(s_u, s_c)\,ds_u\,ds_c$$

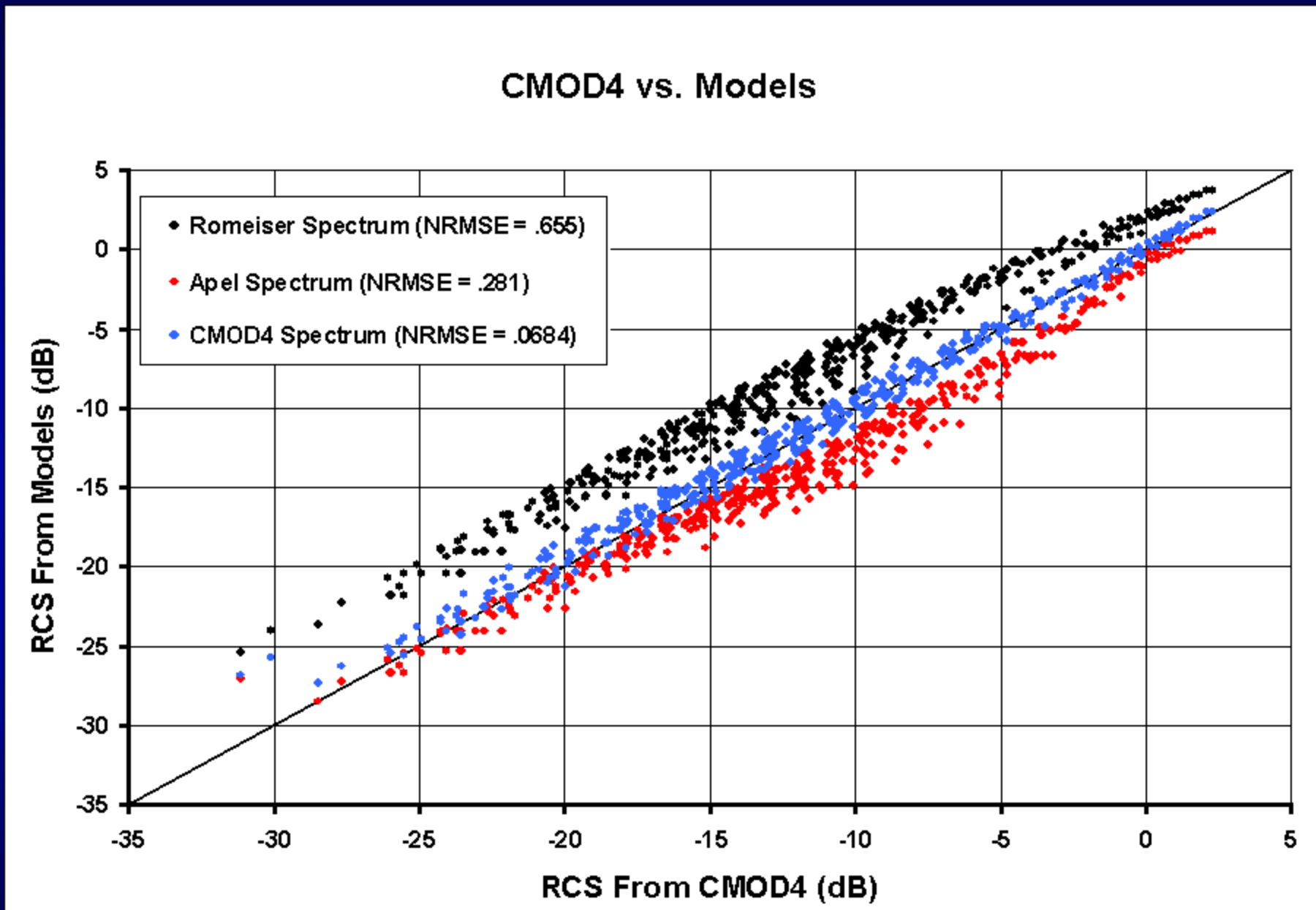
s_u, s_c =upwind,crosswind surface slopes

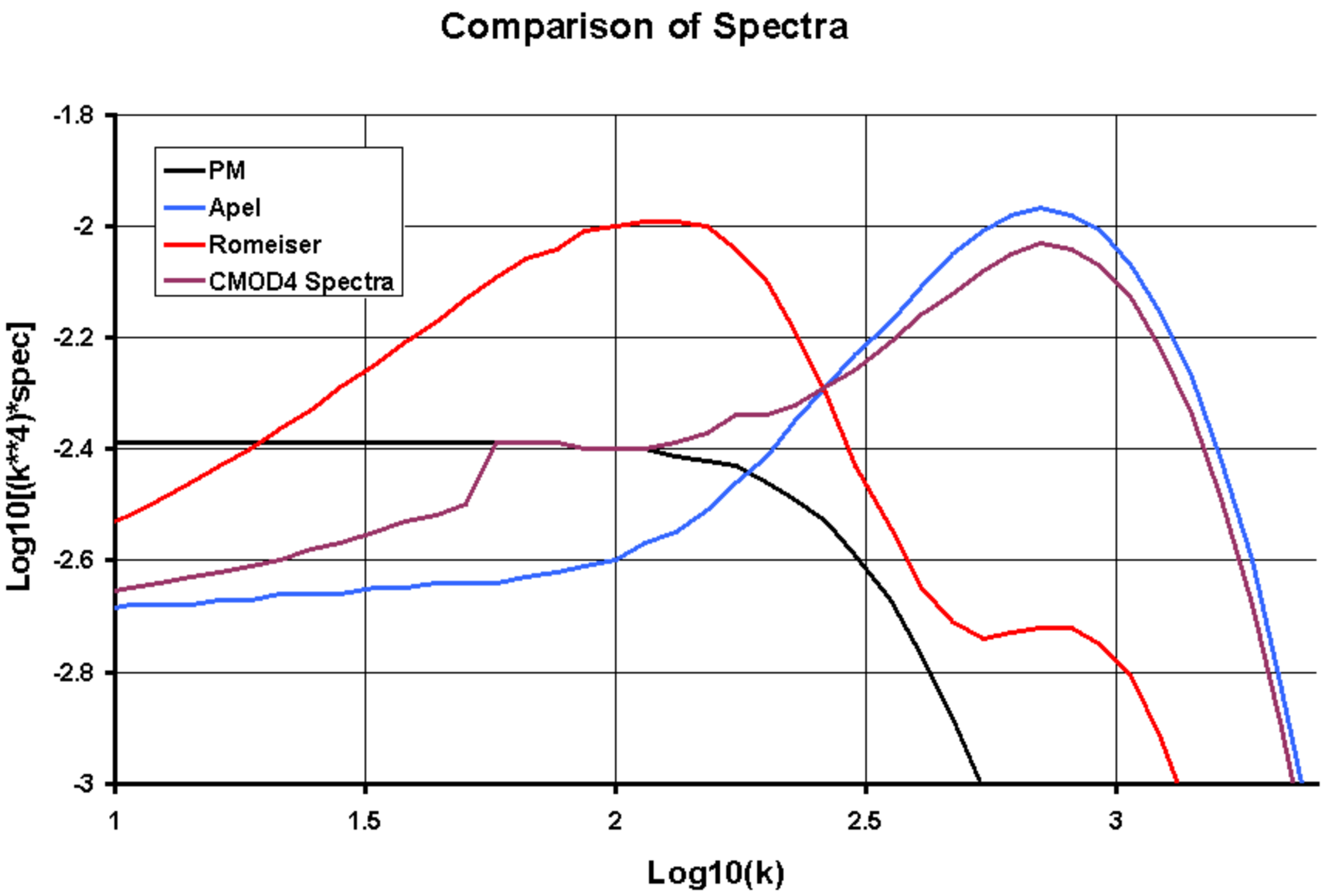
$\sigma_b(s_u, s_c)$ = bragg scattering for a tilted facet

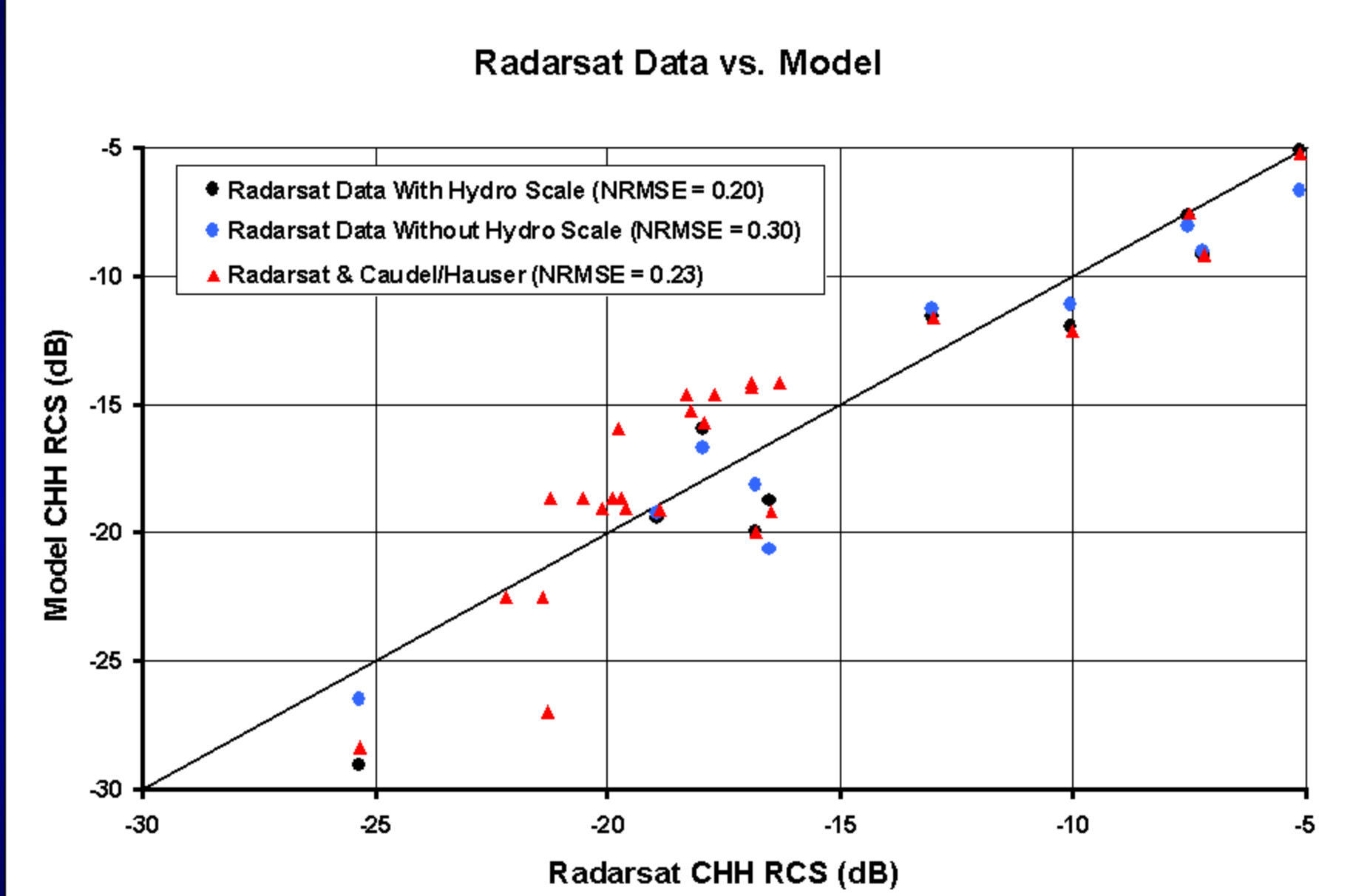
$p(s_u, s_c)$ = probability of a slope s_u, s_c

$h(s_u, s_c)$ = average hydrodynamic modulation over all locations with slopes of s_u, s_c

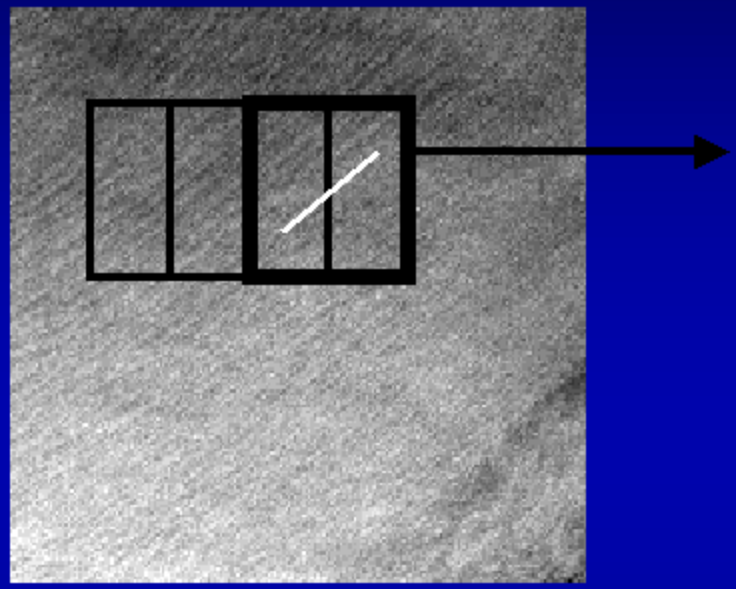
$$h(s_u s_c) \approx \left[1 + \left(\frac{c_{uh}}{\sigma_u^2}\right)s_u + \left(\frac{c_{ch}}{\sigma_c^2}\right)s_c\right]$$


CMOD4 vs. Models
Romeiser Spectrum (NRMSE = .655)
Apel Spectrum (NRMSE = .281)
CMOD4 Spectrum (NRMSE = .0684)
RCS From Models (dB)
RCS From CMOD4 (dB)
5
0
-5
-10
-15
-20
-25
-30
-35


Comparison of Spectra
PM
Apel
Romeiser
CMOD4 Spectra
-1.8
-2
-2.2
-2.4
-2.6
-2.8
-3
Log10[(k**4)*spec]
1
1.5
2
2.5
3
Log10(k)


Radarsat Data vs. Model
Radarsat Data With Hydro Scale (NRMSE = 0.20)
Radarsat Data Without Hydro Scale (NRMSE = 0.30)
Radarsat & Caudel/Hauser (NRMSE = 0.23)
Model CHH RCS (dB)
Radarsat CHH RCS (dB)
-5
-10
-15
-20
-25
-30
-30
-25
-20
-15
-10
-5

Generating Wind Vector Estimates From SAR



Combine wind direction and wind speed estimate to generate a wind vector

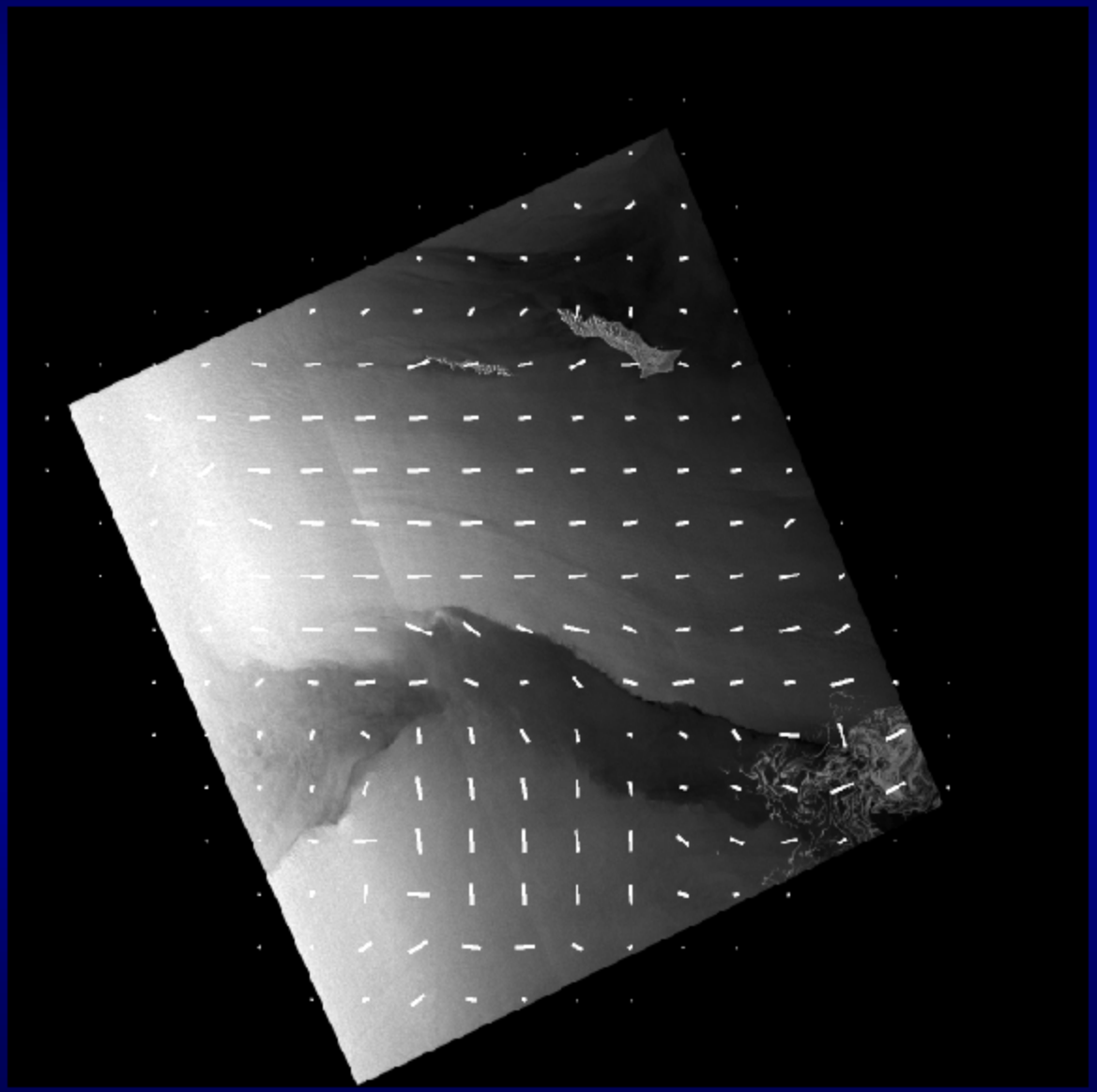
Produce a wind vector every 32 x 32 km (need this to adequately sample scales of 15 km)

Use 48 x 48 km for each estimate (gives a small amount of overlap between estimates)

"Vector" has no head due to 180 degree ambiguity

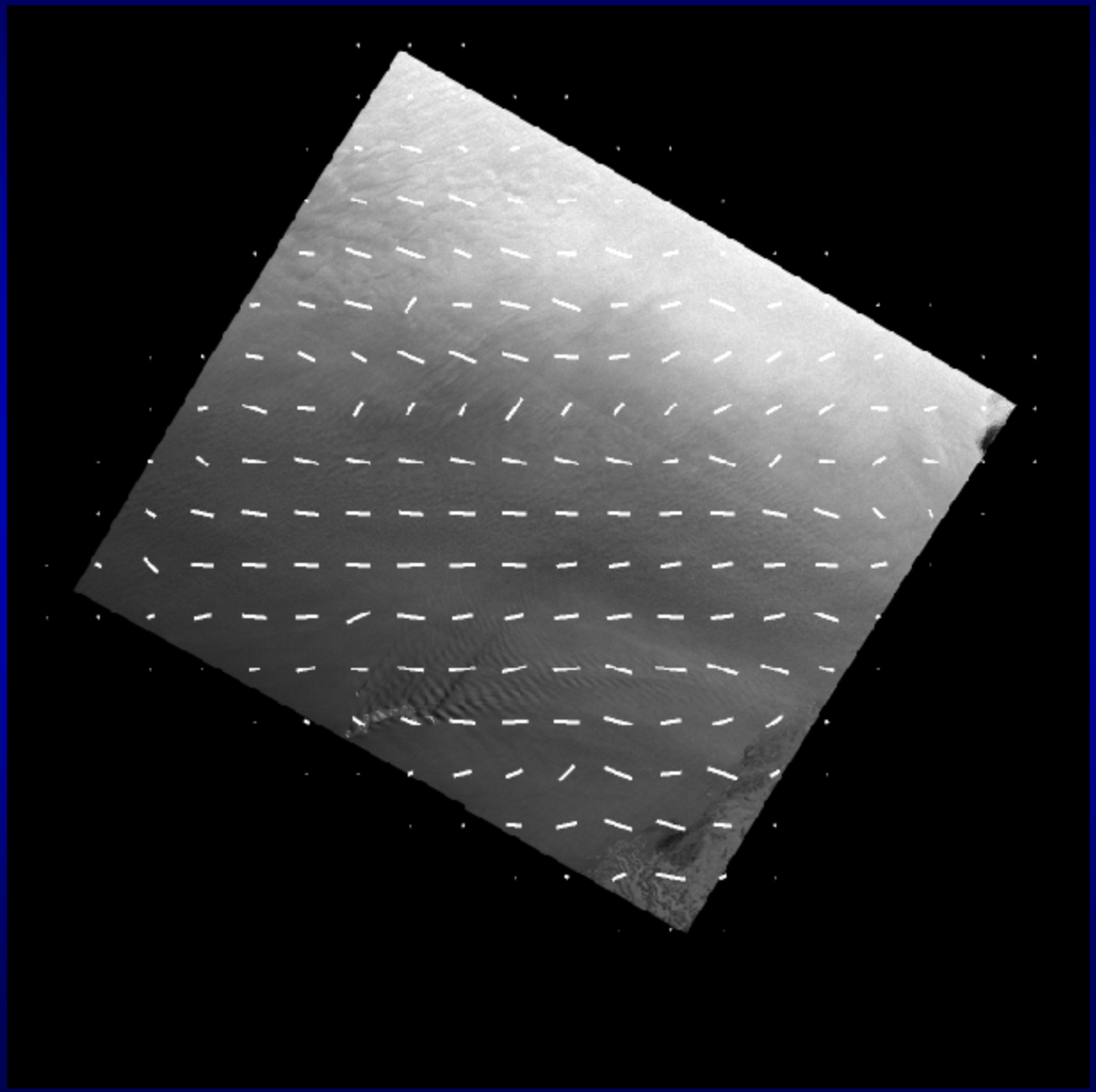
Generating Wind Vector Estimates From SAR

Date: 99001
No Land Mask



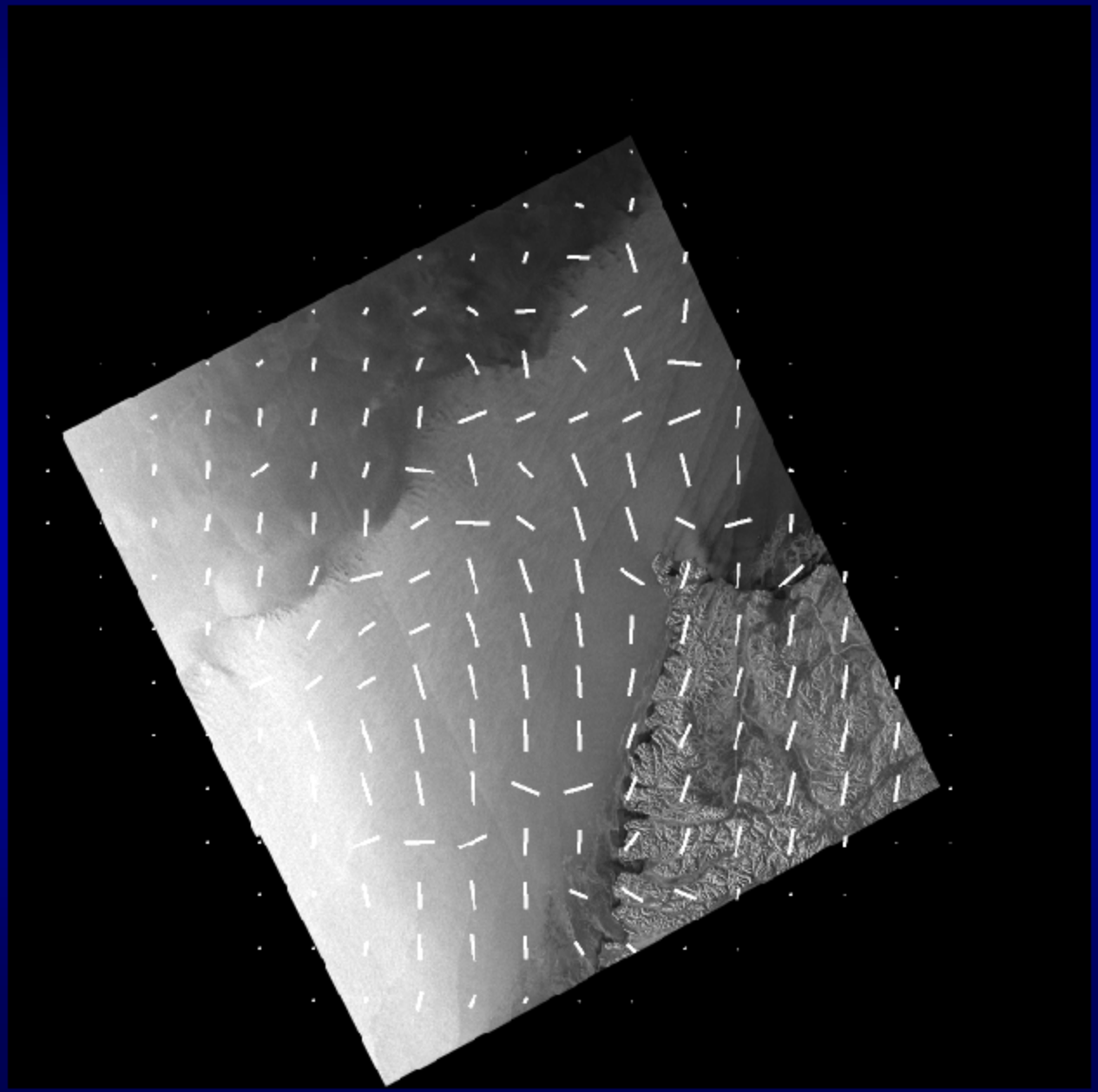
Generating Wind Vector Estimates From SAR

Date: 99005
No Land Mask



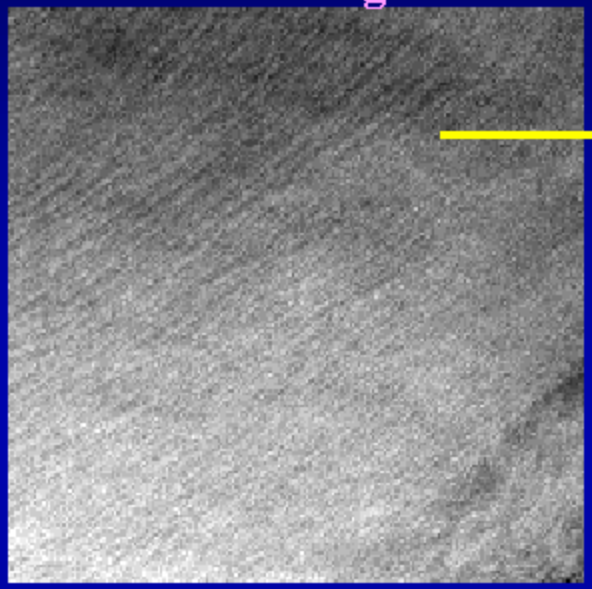
Generating Wind Vector Estimates From SAR

Date: 99336
No Land Mask



Alaska Demo SAR Wind Product

SAR Image



ERIM Int. wind vector algorithm

Ascii File

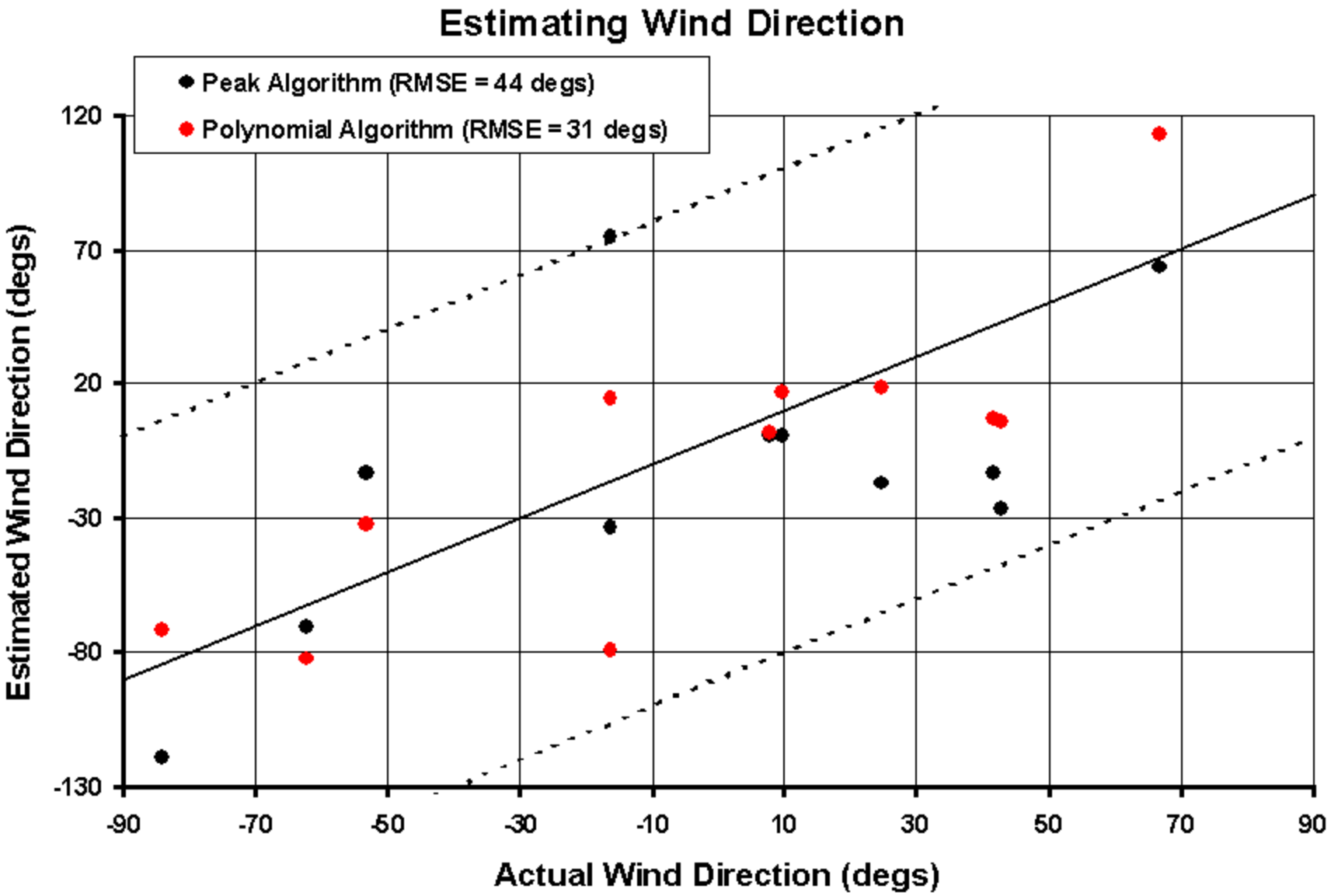
- Header data describing SAR image
- Log of algorithm parameters
- For each wind vector:
  - wind speed / direction
  - line / element of vector
  - latitude / longitude of vector
  - range
  - incidence angle
  - radar cross section

WIPE Server

Validating The Wind Vector Algorithm

- Two previous validation studies were performed using ERS imagery
  - wind speed errors = ±1.2 m/s, wind direction errors = ± 19 degrees (Wackerman et al., ITGRS, 34, 1343-1352, 1996)
  - wind speed errors = ± 2 m/s, wind direction errors = ± 37 degrees (Fetterer et al., ITGRS, 36, 479-492,1998)
- Ongoing activity to validate Radarsat results
  - 9 images included so far, 50 in the wings

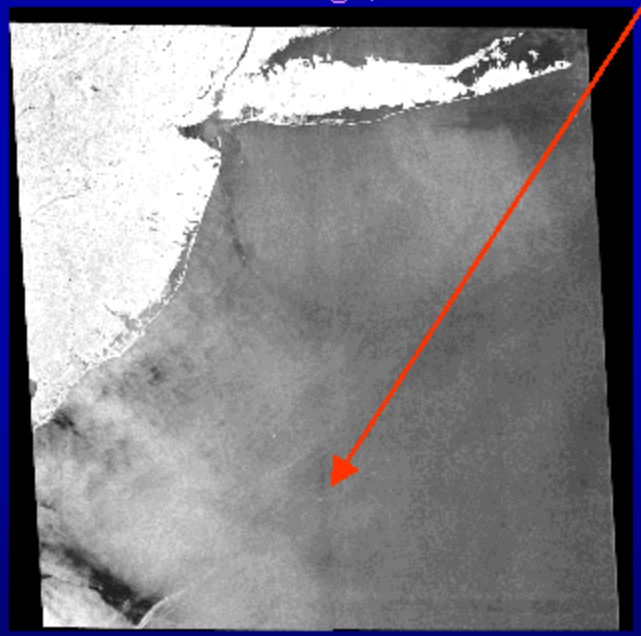
Initial Radarsat Results



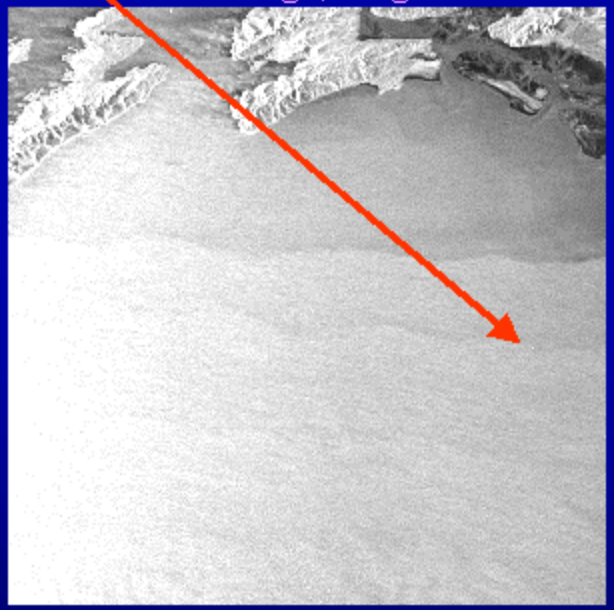
Locating Ships With SAR

Depending on the wind state, bright dots can be seen in SAR images of the ocean corresponding to ships.

Radarsat Image; Low Wind

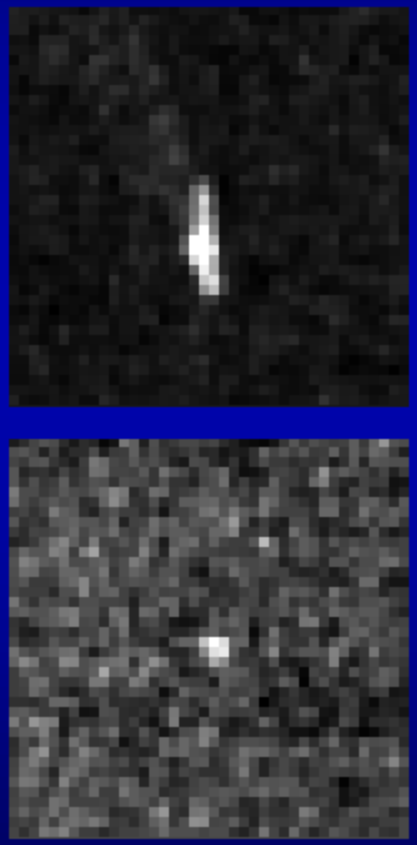


Radarsat Image; High Wind



Locating Ships With SAR (cont.)

Radarsat Signatures of Ships
(50 meter resolution)

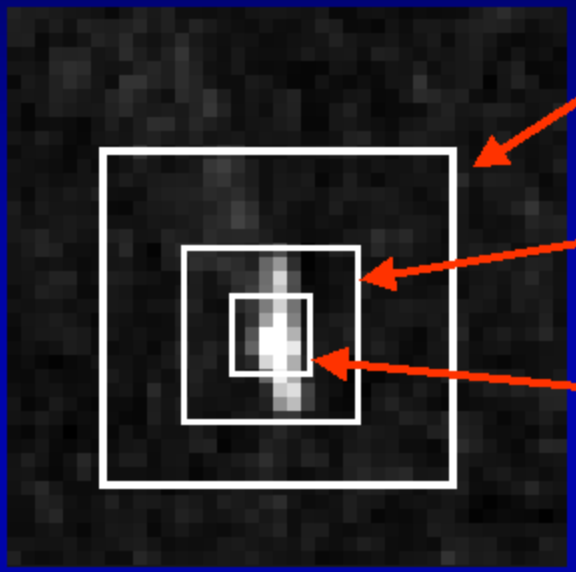


Ships appear as bright blobs against a usually darker water background

Approach is to find blobs that are statistically different from the local background

Need to handle both large and small ships

Locating Ships With SAR (cont.)



Background box
(as big as possible withou including another ship)

Background removal box
(size of the biggest ship)

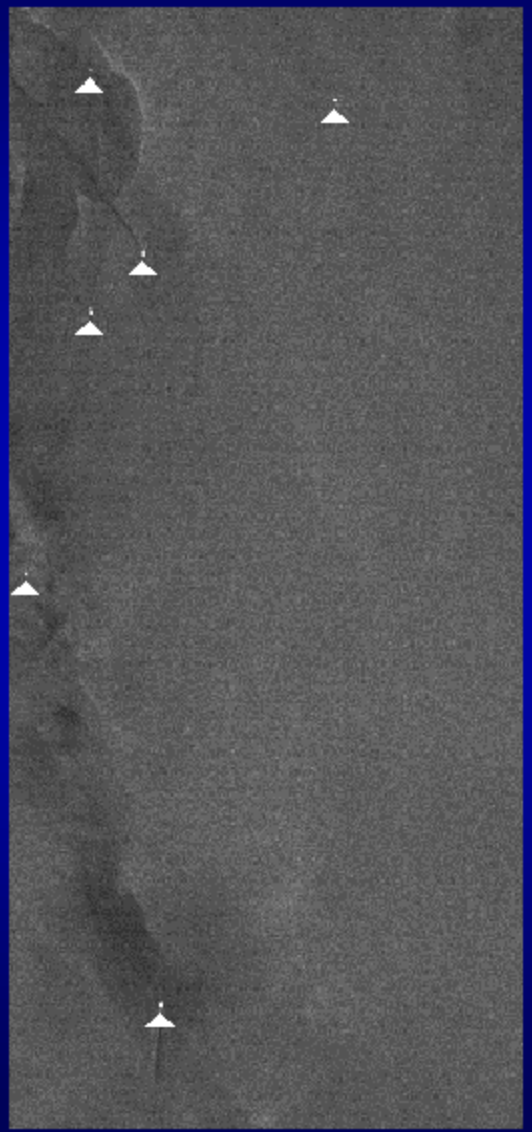
Signal box
(size of the smallest ship)

Calculate the mean of the signal box, m_s

Calculate the mean, standard deviation of the background box ignoring samples within the background removal box, m_b, σ_b

Form the metric $d = \frac{\sqrt{N_s}(m_s - m_b)}{\sigma_b}$ where Ns = number of samples in signal box

Locating Ships With SAR (cont.)

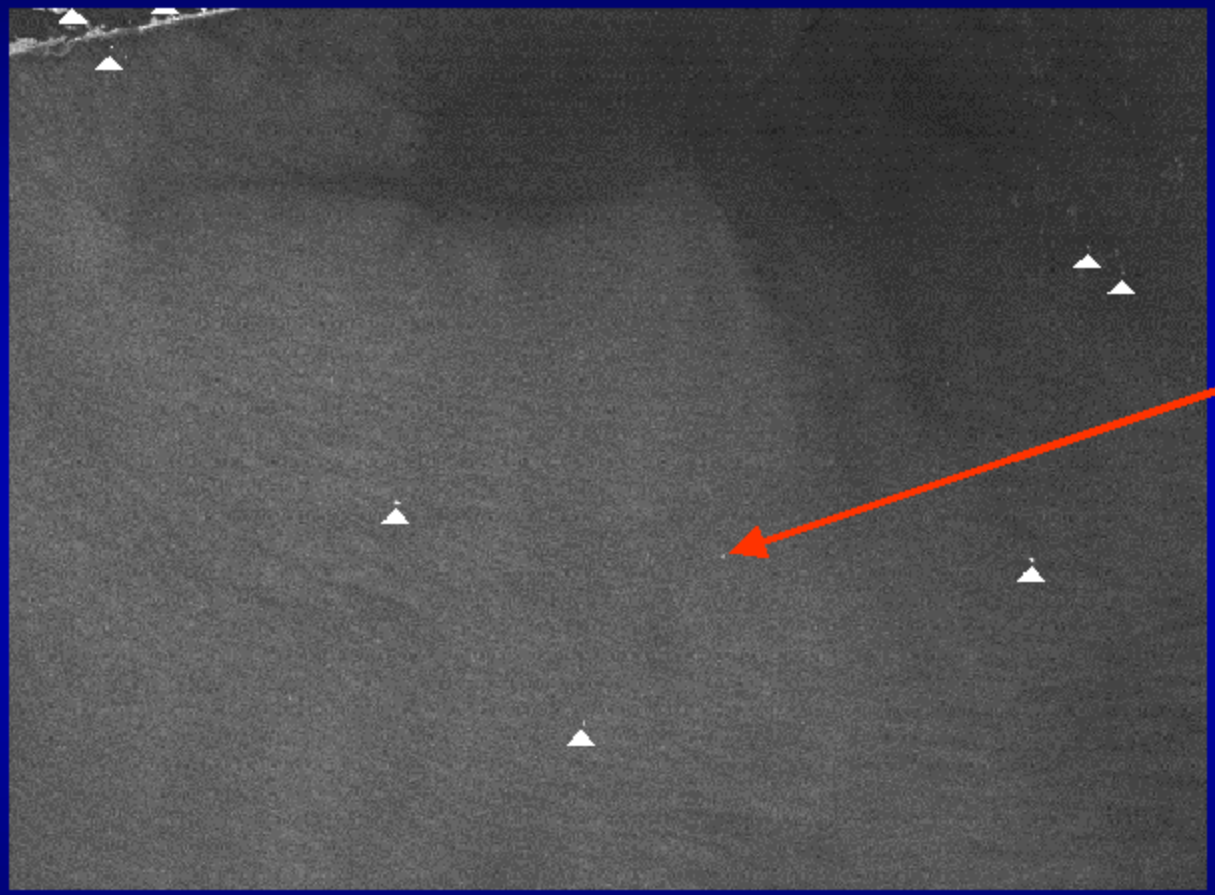


Move the background box through the image, flagging each location for which the d metric is larger than a threshold.

Throw away locations where the total energy from the signal box is below a threshold (eliminates noise spikes)

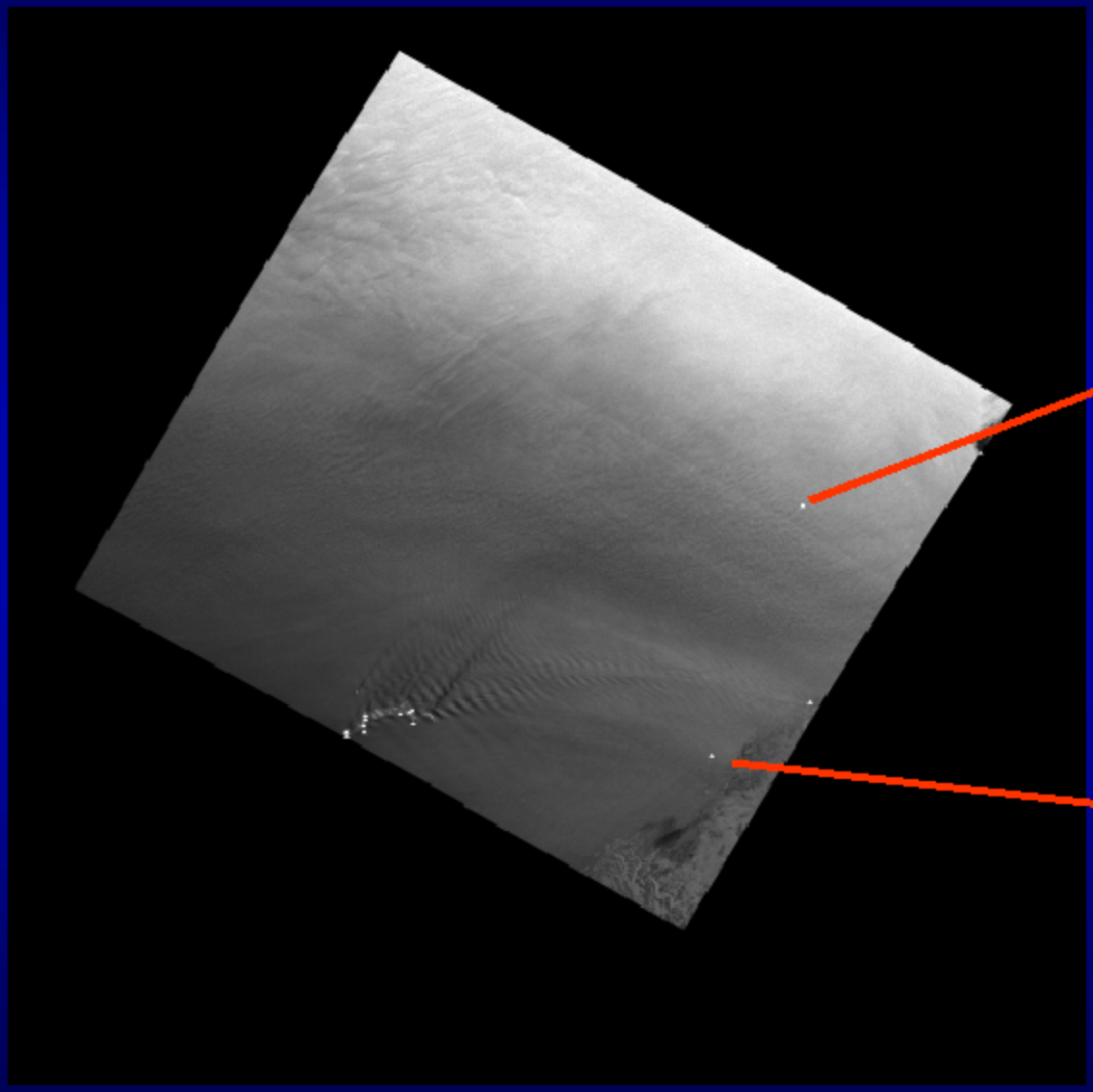
Use a land mask to throw away all detection on land (keep a 500m border in case there are registration errors

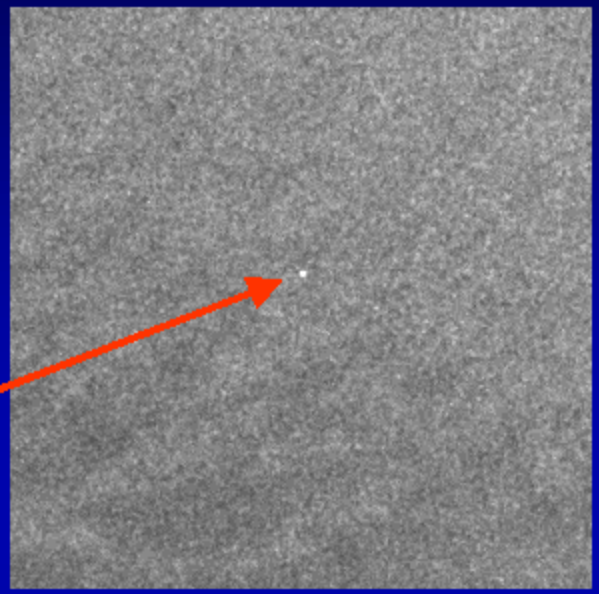
Locating Ships With SAR (cont.)

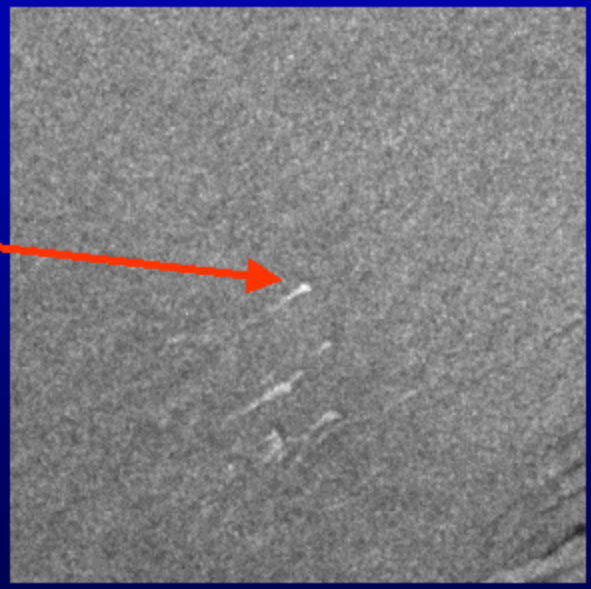


Need to determine threshold for d metric that is a compromise between false alarms and missed detection

Locating Ships With SAR (cont.)

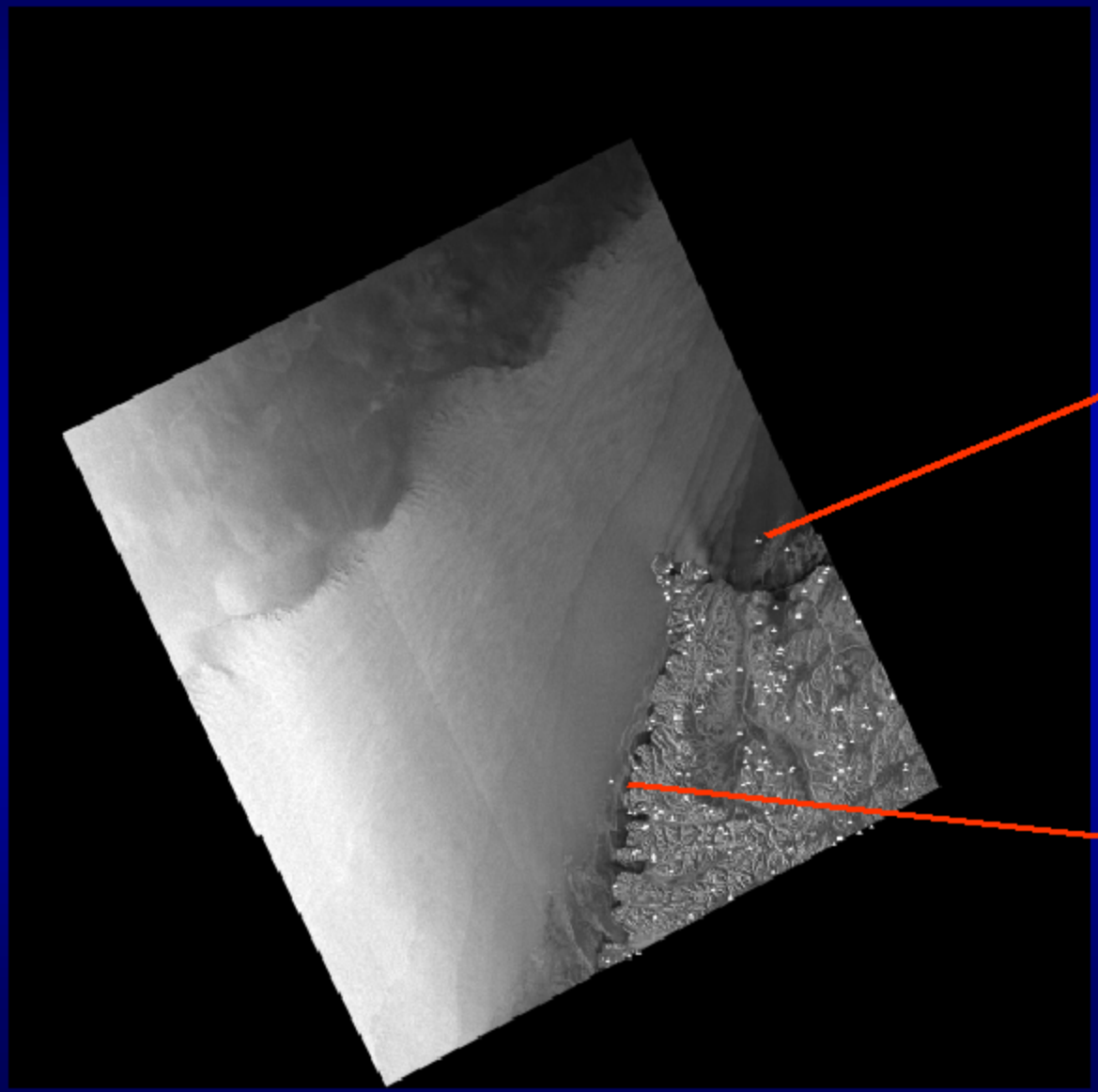


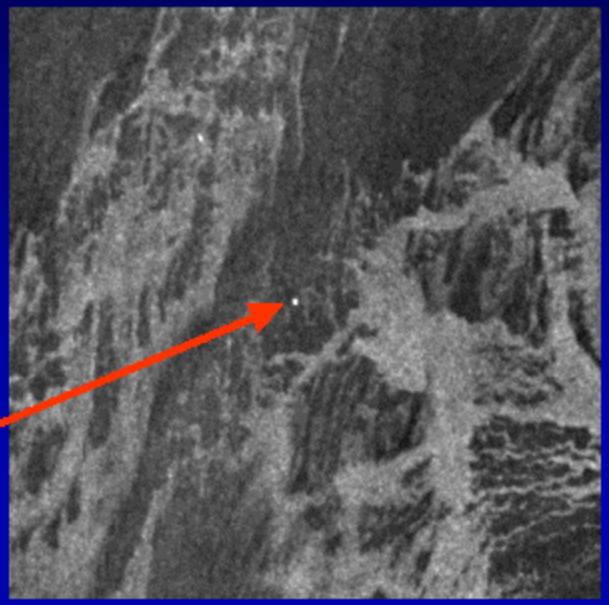


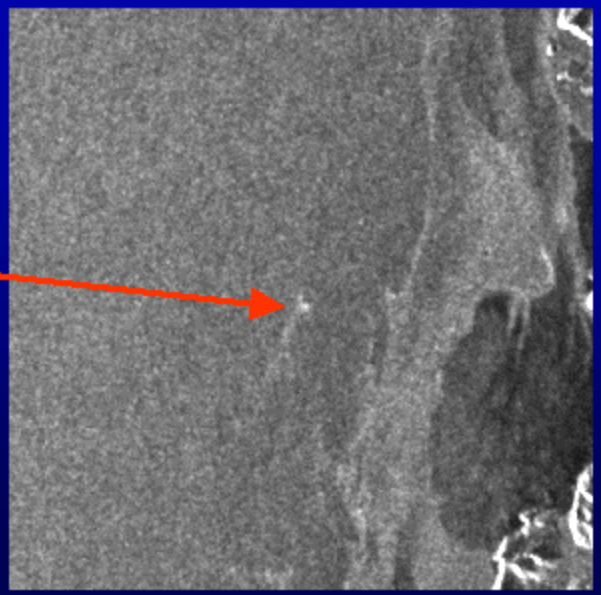


Date: 99005 No Land Mask

Locating Ships With SAR (cont.)



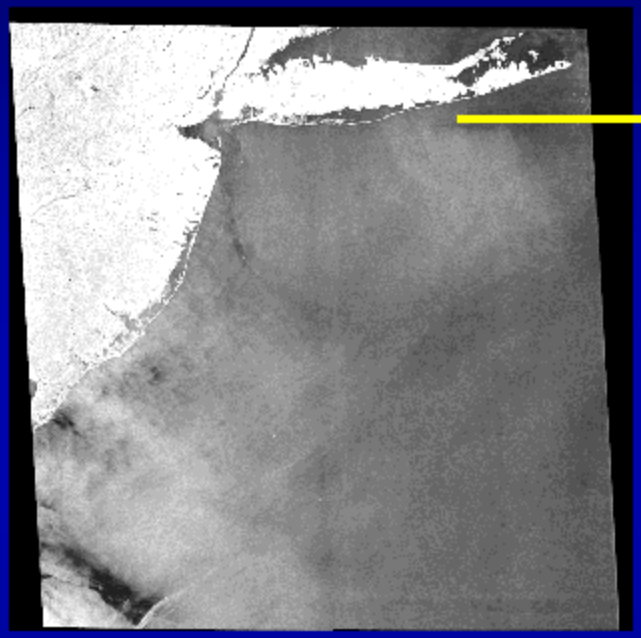




Date: 99336 No Land Mask

Alaska Demo SAR Ship Product

SAR Image



ERIM Int. Ship detection algorithm

Ascii File

- Header data describing SAR image
- Log of algorithm parameters
- For each ship detection:
  - line / element of ship
  - latitude / longitude of ship
  - d statistic
  - energy in signal box
  - range
  - incidence angle
  - wind speed (assuming wind direction is SAR look direction

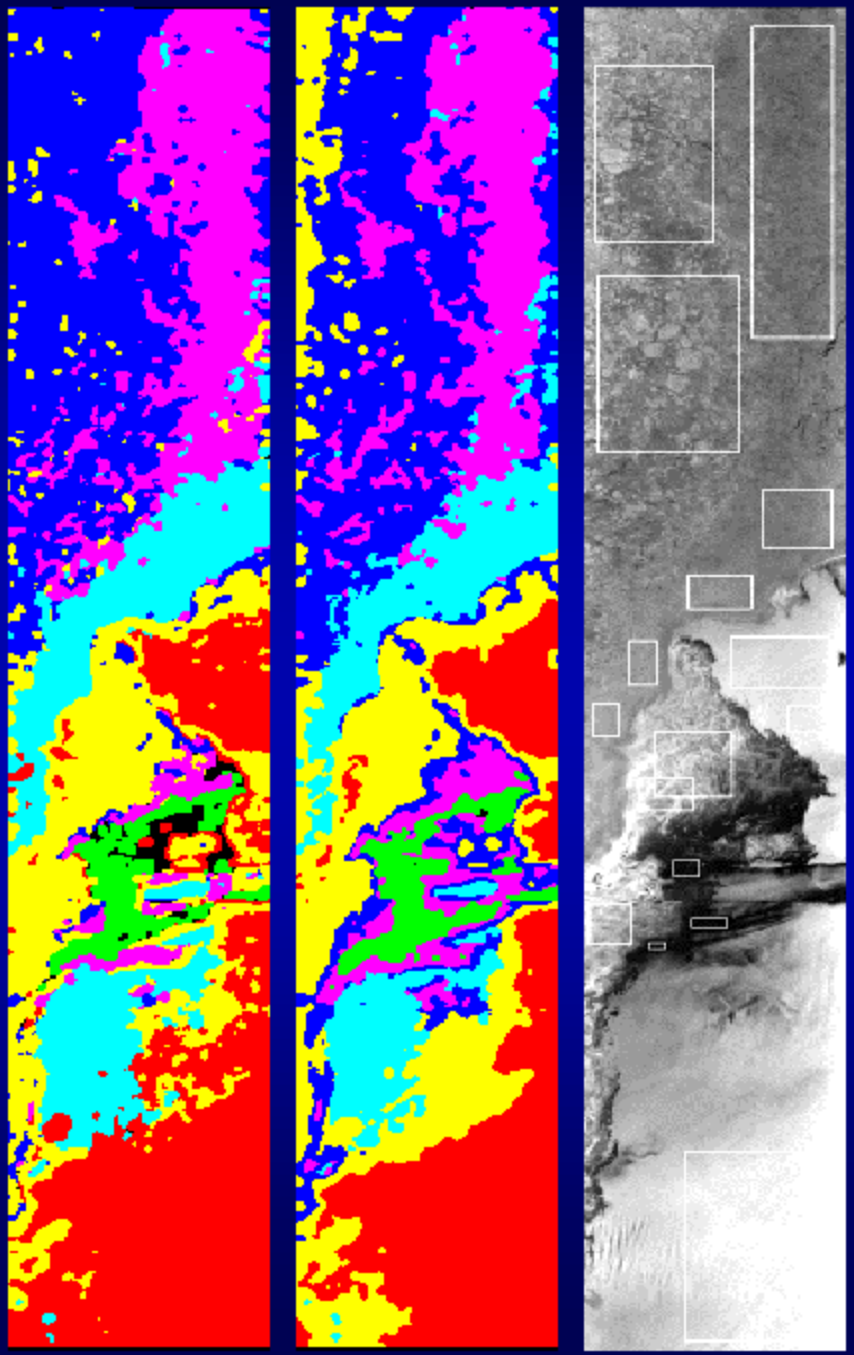
WIPE Server

Validating The Ship Detection Algorithm

- To date algorithm parameters have been set by a manual interpretation of the image
  - Did we find all of the bright blobs
  - Do not know which are really ships, whether there are ships we can not see
- Over the course of the demonstration, need to get whatever ground truth is available

Future Demo Algorithms

- As discussed in the Introduction To SAR presentation, there are a number of oceanic parameter being estimated from SAR which could be added in the future
  - waves, current fronts, bathymetry
- Current plans for next year are to add an ice classification algorithm based on extending ERS results
  - will also provide a mask for ship detections



5 March 92
SIZEX
ERS-1 Image

Boxes indicate training regions

Ice Classes

- Not Classified
- Open Water
- New Ice
- Grease Ice
- Congealed Pancake
- MY Floes in FY
- FY Ice